

## The Concentration and Stability of Gun Violence at Micro Places in Boston, 1980–2008

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**Abstract** Boston, like many other major U.S. cities, experienced an epidemic of gun violence during the late 1980s and early 1990s that was followed by a sudden large downturn in gun violence in the mid 1990s. The gun violence drop continued until the early part of the new millennium. Recent advances in criminological research suggest that there is significant clustering of crime in micro places, or “hot spots,” that generate a disproportionate amount of criminal events in a city. In this paper, we use growth curve regression models to uncover distinctive developmental trends in gun assault incidents at street segments and intersections in Boston over a 29-year period. We find that Boston gun violence is intensely concentrated at a small number of street segments and intersections rather than spread evenly across the urban landscape between 1980 and 2008. Gun violence trends at these high-activity micro places follow two general trajectories: stable concentrations of gun assaults incidents over time and volatile concentrations of gun assault incidents over time. Micro places with volatile trajectories represent less than 3% of street segments and intersections, generate more than half of all gun violence incidents, and seem to be the primary drivers of overall gun violence trends in Boston. Our findings suggest that the urban gun violence epidemic, and sudden downturn in urban gun violence in the late 1990s, may be best understood by examining highly volatile micro-level trends at a relatively small number of places in urban environments.

**Keywords** Guns · Gun violence · Hot spots · Epidemic

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## Introduction

Beginning in the late 1980s and continuing through the early 1990s, the United States experienced a dramatic increase in firearms violence reaching its zenith in 1993, with 17,075 homicides committed with firearms (Blumstein 1995; Cook and Laub 1998, 2002).<sup>1</sup> This dramatic increase was followed by a puzzling decrease. By 2000, gun homicide had decreased by 40% to 10,203 incidents and remained relatively low with 10,661 gun homicides in 2004. Criminologists and public policy analysts have examined a wide range of factors that may have been associated with this drop, including innovative policing strategies, a strong economy, higher imprisonment rates, stronger gun control, and stabilizing street-level drug markets (Blumstein and Wallman 2000). In recent years, however, some observers have expressed concern of a resurgence of urban gun violence that was developing nationwide (e.g., Police Executive Research Forum 2006). For example, in 2005 the U.S. Bureau of Justice Statistics reported that the number of gun homicides had increased by 6% to 11,346. Fortunately, this increase seemed to be short lived as the Federal Bureau of Investigation recently estimated that the number of gun homicides once again declined to 10,086 in 2007.<sup>2</sup>

Some research equated the epidemic of firearms violence that spanned the late 1980s and early 1990s with a “flood in a canyon” as it was intensely concentrated in disadvantaged inner-city areas and among young minority males, who were often gang-involved and well known to the criminal justice system (Cook and Laub 2002; Braga 2003). What is more, criminological evidence on the concentration of crime in a small number of highly active micro places suggests that a few “hot spot” locations in disadvantaged urban neighborhoods may be primarily responsible for overall citywide gun violence trends (see, e.g., Sherman et al. 1989; Weisburd et al. 2004). Unfortunately, few scientific inquiries have examined the spatial distribution of gun violence during these dramatic shifts, and when they have, they have typically not looked at units of analysis smaller than the Census tract or block group. If citywide gun violence epidemics can be best understood in terms of large changes at a few micro places, these findings would suggest that an array of violence prevention programs involving the deployment of criminal justice, social service, and community-based resources should be similarly concentrated rather than diffused across larger urban areas.

In this paper, we use growth curve regression models to uncover distinctive developmental trends in gun assault incidents at street segments and intersections in Boston between 1980 and 2008. The main goal of this paper is to examine the ways in which crime patterns in micro places influence the vanguard of crime trends in the City of Boston during the epidemic and post-epidemic periods. In support of micro-places research, our findings suggest that an extremely small percentage of micro places that exhibit relatively stable crime trajectories are responsible for the majority of gun violence trends in Boston during this time period. In fact, only 5% of street segments and intersections in Boston are responsible for 74% of serious gun assault incidents even when controlling for prior levels of gun violence and existing linear and nonlinear trends. These highly active places account for the bulk of the increase in gun violence during epidemic years and the decrease in gun violence during crime drop years.

<sup>1</sup> Unless otherwise noted, the homicide data in this paragraph were acquired from the U.S. Bureau of Justice Statistics (accessed May 20, 2009) <http://www.ojp.usdoj.gov/bjs/homicide/tables/weaponstab.htm>.

<sup>2</sup> [http://www.fbi.gov/ucr/cius2007/offenses/expanded\\_information/data/shrtable\\_07.html](http://www.fbi.gov/ucr/cius2007/offenses/expanded_information/data/shrtable_07.html) (accessed May 20, 2009).

The first two sections of this paper briefly summarize the existing literature on crime and place and the nature of the gun violence epidemic between the late 1980s and early 1990s. These sections pay particular attention to the relevant dimensions of gun violence in Boston. The next three sections describe the data collection methodology, detail the statistical models used to analyze the data, and present the results of the quantitative analyses. The conclusions drawn from the research findings are discussed in the final section.

### The Concentration and Stability of Crime in Micro Places

The observation that the distribution of crime varies within and between neighborhoods has existed for some time (see, e.g., Shaw and McKay 1942). However, due to limited analytical capacities, little empirical research has examined this variance beyond the community or neighborhood level of analysis with the U.S. Census tract or block group serving as the most common units of analysis. With the advent of powerful computer systems and software packages in the late 1980s, analysts began to further hone their focus on even smaller geographic units of analysis. Two well-known cross-sectional studies found that some 5% of city addresses generated over 50% of citizen emergency calls for service to the police in Boston (Pierce et al. 1988) and Minneapolis (Sherman et al. 1989). Even within high-crime neighborhoods, these studies found that crime clusters at a few discrete “hot spot” micro places, leaving blocks of areas within neighborhoods relatively crime-free. Put another way, not every block or corner in a high crime neighborhood experiences high levels of crime. Rather, certain blocks or address experience high levels of crime, while others are relatively crime free. Further, research by Taylor and Gottfredson (1986) revealed conclusive evidence that links this spatial variation to the physical and social characteristics of particular blocks and multiple dwellings within a neighborhood.

More recently, a research team from the University of Maryland analyzed crime incidents at the level of street segments in Seattle over a 14 year period and found that, year to year, about 50% of the crime was concentrated in approximately 4.5% of street segments (Weisburd et al. 2004). Of course, the concentration of crime year to year does not preclude the possibility that each year different crime hot spots would develop, or that hot spots in 1 year would naturally become cool the next. For this reason, the Maryland research team also examined the developmental trends of crime at street segments in Seattle over the 14 year period (Weisburd et al. 2004). Using semi-parametric, group-based trajectory procedures (i.e., TRAJ models, see Nagin 1999), the approximately 30,000 street segments in Seattle were grouped into trajectories with similar developmental trends over time. These analyses revealed that there was a high degree of stability of crime at micro places over time. In other words, crime remained concentrated in a small number of micro places in Seattle rather than spread across the city over time. Weisburd et al. (2004) also found that a relatively small proportion of places belonged to groups with steeply rising and or declining trajectories and that these places were primarily responsible for overall crime trends in Seattle between 1989 and 2002.

Several other studies have come to similar conclusions about the stability of crime at specific micro places over time. Spelman (1995) analyzed calls-for-service at high schools, housing projects, subway stations, and parks in Boston, and found that the risks at these public places remained fairly constant over time. Taylor (1999) also reports evidence of a

high degree of stability of crime at place over time, examining crime and fear of crime at ninety street blocks in Baltimore, Maryland using a panel design with data collected in 1981 and 1994 (see Robinson et al. 2003; Taylor 2001). Data included not only official crime statistics, but also measures of citizen perceptions of crime and observations of physical conditions at the sites. Although Taylor and his colleagues observed significant deterioration in physical conditions at the blocks studied, they found that neither fear of crime nor crime showed significant or consistent differences across the two time periods.

### The Spatial Nature of the Gun Violence Epidemic

Although the direct causes of the gun violence epidemic in the late 1980s and early 1990s remain somewhat elusive, a concrete story emerged that seems to fit with experience and research evidence. Moore and Tonry's (1998) synthesis of key events provides a useful framework and is quickly summarized here. Building off of the work of Wilson (1987, 1996), Moore and Tonry recounted how the deindustrialization of the economy during late seventies and early eighties fundamentally changed the structural factors conditions in inner-city minority communities. The social and economic structure of many urban neighborhoods collapsed under a variety of social and economic pressures as employment opportunities, business, and the middle class fled the inner-city. A subsequent cascade of negative conditions decimated inner city neighborhoods, including the disruption of families, increased mass incarceration, and heightened social and economic isolation. Gangs continued to flourish as youth responded to geographic and structural isolation by turning to these groups in search of affiliation, security, and, in some cities, new economic opportunities (see, e.g., Hagedorn 1988).

Moore and Tonry's (1998) review then suggests that an epidemic of crack cocaine hit many of these troubled communities during the mid to late eighties (see also Blumstein 1995). Some existing youth gangs and other non-gang involved youth participated in street-level drug markets and armed themselves with guns to protect themselves and resolve business disputes. The arming of youth participating in street drug sales produced both dangerous conditions on the street and a cultural style that encouraged other youth to acquire guns in response. A large supply of available guns made it possible for other youth to acquire guns out of self-protection, style, and status concerns. The widespread arming of youth in these disadvantaged neighborhoods made everyday conflicts much more lethal.

This account suggests strong spatial dimensions to the spread of gun violence in U.S. cities over the course of the late 1980s and early 1990s. Since many homicides, whether gang-related or not, are retaliatory in nature (Block 1977; Wolfgang 1958), homicides may themselves instigate a sequence of events that leads to further violence in a spatially channeled way. As such, a homicide in one neighborhood may spark a retaliatory killing in a nearby neighborhood. Most homicides occur among persons who are known to each other (Reiss and Roth 1993) and these networks of associations can follow geographic vectors across and within neighborhoods and specific places (Papachristos 2009). As such, several studies attempted to understand the nature of the gun violence epidemic by examining the geographic distribution of gun violence over time. These analyses generally reported strong spatial associations between homicide concentrations and the spatial distribution of poor, black neighborhoods that experience gang, drug, and gun problems (Cohen and Tita 1999; Rosenfeld et al. 1999). These analyses also sought to determine whether gun violence diffused across urban landscapes over time.

In Pittsburgh, Cohen and Tita (1999) reported that spatial diffusion of increasing homicide rates across neighboring U.S. Census tracts was evident only during the year of peak growth in total homicides, when high local rates of youth-gang homicides were followed by significant increases in neighboring youth-nongang rates. Otherwise, Cohen and Tita (1999) reported that increases in both youth-gang and youth-nongang homicides generally occurred simultaneously in non-neighboring Census tracts. Using Census block groups as the unit of analysis, Rosenfeld et al. (1999) provided some evidence that gang-motivated homicides in St. Louis spread in a contagious manner and speculated that gang membership may be the mechanism by which such events spread. A separate analysis of the distribution of homicides in 78 counties in and around St. Louis reported strong evidence of the highly localized nature of spatial dependencies in homicides over time at the county-level and some modest evidence of spatial diffusion of homicide in particular urban counties, and presented findings that affluent and rural areas serve as barriers against the spread homicides across counties (Messner et al. 1999).

More recently, Griffiths and Chavez (2004) merged Exploratory Spatial Data Analysis (ESDA) and TRAJ models to identify total, street gun, and other weapon homicide trajectories across 831 Census tracts in Chicago between 1980 and 1995. Griffiths and Chavez (2004) reported a weapon substitution effect in violent neighborhoods (i.e., Census tracts) that are proximate to one another, a defensive diffusion effect of exclusively street gun-specific homicide increases in neighborhoods bordering the most violent areas, and a spatial decay effect of temporal homicide trends in which the most violent areas are buffered from the least violent by tracts experiencing mid-range levels of homicide over time. The Census tracts associated with the largest increases in street gun homicide rates were characterized as areas associated with high-levels of gun violence, drug market activity, and street gang activity. Other studies have revealed that gang wars over drug markets in Chicago were prevalent between 1987 and 1994 and concentrated in a small number of hot spot locations (Block and Block 1993; Block et al. 1996).

### The Trajectory and Nature of Gun Violence in Boston, 1980–2008

Like many American cities during the late 1980s and early 1990s, Boston suffered an epidemic of gun violence that had its roots in the rapid spread of street-level crack-cocaine markets (Kennedy et al. 1996; Braga 2003). Measured as a homicide problem, Boston experienced a dramatic increase in the number of fatal gun shot wound victims. During the “pre-epidemic” years of 1980 through 1988, Boston averaged approximately 40 gun homicides per year. The number of gun homicides increased to 57 victims in 1989 and peaked at 86 victims in 1990. While gun homicide subsequently decreased from the peak year, the yearly number of victims remained high between 1991 and 1995 as Boston averaged nearly 62 gun homicides per year.<sup>3</sup> In 1996, the number of gun homicides dropped steeply to 38 victims and, in 1999, Boston experienced only 19 gun homicides.<sup>4</sup>

<sup>3</sup> After street crack-cocaine markets stabilized, drug-related violence decreased in Boston. Unfortunately, serious gun violence had become “decoupled” from the crack trade. Guns were used by Boston youth to settle disputes that were once dealt with by fists, sticks, and knives (Kennedy et al. 1996; Braga 2003).

<sup>4</sup> An interagency problem-oriented policing intervention, which tightly focused criminal justice attention on a small number of chronically offending gang-involved youth, was associated with the significant reduction in youth homicide and non-fatal gun violence when it was operational between 1996 and 2000 (Braga et al., 2001). The implementation and impact of the Operation Ceasefire intervention has been extensively documented elsewhere (see, e.g., Kennedy et al. 1996, 2001; Braga et al. 2008) and is not the subject of this paper.

Unfortunately, beginning in 2001, the number of gun homicides steadily grew to a second peak of 55 victims in 2006. In 2007 and 2008, the number of gun homicides decreased modestly to 52 and 49 victims, respectively.

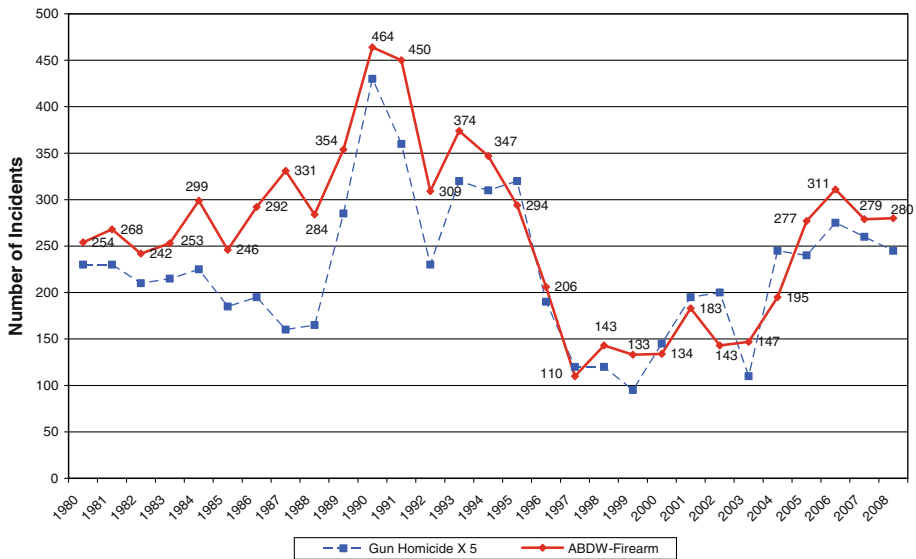
The two periodical increases in Boston gun violence have been characterized as highly concentrated among a small number of people and in a small number of places. Problem analysis research conducted in the mid-1990s (Kennedy et al. 1996) and in the mid-2000s (Braga et al. 2008) describe gun homicide as being driven by approximately 1% of the city youth aged 15–24 who participated in ongoing gang conflicts governed by disrespect and status concerns and who were very well known to the criminal justice system. These accounts also pointed to the strong geographic concentration of serious gun violence. Kennedy et al. (1997) revealed that gang turf covered only 3.6% of Boston's 48 square miles but experienced 24% of gun assaults and 27% of youth homicide in 1994. More recently, Braga et al. (2008) reported that gun violence hot spots covered only 5.1% of Boston's geography but generated nearly 53% of fatal and non-fatal shootings. Braga et al. (2008) also noted that these gun violence hot spots were largely the same places that experienced the bulk of gun violence during the epidemic years of the late 1980s and early 1990s. Unfortunately, these cross-sectional studies did not attempt any longitudinal analysis of gun violence at specific places over time to determine whether the same locations were indeed generating a bulk of citywide gun violence trends.

While research in Boston and other U.S. cities has examined various dimensions of the crime epidemic and the subsequent drop (e.g., the role of gangs, guns, and drugs), very little attention has been directed towards the spatial analysis of these epidemics. When spatial analysis has been done, it has been at the city, county, or Census tract-level which takes for granted the role of micro places in these epidemics. Indeed, the existing spatial diffusion analyses have not seriously considered the existence of micro-level variation of gun violence at particular street corners and street blocks within larger areal units. In this paper, we hope to address this gap in the literature by examining how the growth and decline of serious gun violence in Boston are influenced by different micro-crime trajectories at street segments and intersections. As such, we examine the salience of micro-level units of analysis in understanding citywide gun violence trends rather than conducting analyses of spatial diffusion processes.

## Data and Unit of Analysis

In this study, we measure serious gun violence by using computerized records of Boston Police Department official reports of Assault and Battery by Means of a Deadly Weapon—Firearm (ABDW—Firearm) incidents between January 1, 1980 and December 31, 2008. Incident reports are generated in the Boston Police Department by detectives or police officers after an initial response to a request for police service. These data were used to cast a wider net in examining the spatial distribution of gun violence in Boston and to increase the stability of our estimates through their larger yearly numbers over time. In the State of Massachusetts, ABDW—Firearm incidents essentially represent shooting events where guns were fired and victims were physically wounded by the fired bullets.<sup>5</sup> Boston experienced 7,602 ABDW—Firearm incidents over the 29-year study period. As Fig. 1 shows, ABDW—Firearm incidents followed essentially the same trajectory as gun homicide in Boston between 1980 and 2008 (gun homicide counts were multiplied by five to show

<sup>5</sup> See Massachusetts General Laws, Chap. 265, Sect. 15A.



**Fig. 1** Gun homicide and ABDW-firearm incident trends in Boston, 1980–2008.  $N = 7,602$  incidents over 29 years

the trend on the same graph). ABDW-Firearm incidents were general stable during the early 1980s, climbed to a peak of 464 incidents in 1990, fell dramatically to a low of 110 incidents in 1997, and then rose again to a second peak of 311 incidents in 2006. These Boston-specific trends are representative of national-level trends in serious gun violence (see Cook and Laub 2002).

It is well known that police incident data, such as the FBI's Uniform Crime Reports, have shortcomings. For instance, crime incident data are biased by the absence of crimes not reported by citizens to the police and by police decisions not to record all crimes reported by citizens (see Black 1970). Although incident reports have flaws, careful analyses of these data can yield useful insights on crime (Schneider and Wiersema 1990). Moreover, official police incident data are widely used for assessing trends and patterns of gun crime (Blumstein 1995; Cook and Laub 2002) and the evaluation of gun violence reduction programs (see, e.g., Sherman and Rogan 1995; McGarrell et al. 2001; Cohen and Ludwig 2003).

The geographic units of interest for our study are micro places, defined as street segments and intersections, in Boston, Massachusetts. Street segments, sometimes referred to as street block faces, were defined as “the two block faces on both sides of a street between two intersections” (Weisburd et al. 2004, p. 290). Drawing on the influential work of David Weisburd et al. (2004), we selected the street segment because it allowed a unit large enough to avoid unnecessary coding errors associated with smaller units such as addresses (Klinger and Bridges 1997; Weisburd and Green 1994), and small enough to avoid aggregation that might hide specific micro-level place trends. Street block faces have also been recognized as useful units of analysis for micro places that capture regularly recurring rhythms of social activity within the small physical boundary of a street segment (Hunter and Baumer 1982; Taylor et al. 1984; Weisburd et al. 2004).

Intersections, often called street corners, were defined as locations where two or more streets crossed. Intersections were included in this analysis for practical and substantive

reasons. When crimes occur at an intersection, police often record the location on the incident report as the intersection of two streets (e.g., “Massachusetts Avenue & Tremont Street”) rather than assigning a specific address (e.g., “1010 Massachusetts Avenue”) on a street segment. Rather than excluding events that were recorded at intersections, we decided to include intersections as a unit of analysis in the study. Previous studies excluded crime incidents at intersections for technical reasons, such as concerns over assigning these events to adjoining street segments (see Weisburd et al. 2004, p. 291). Substantively, many sociological inquiries have found that some inner-city residents meet, socialize, and sometimes live out significant portions of their daily lives on street corners (e.g., Liebow 1967; Whyte 1943). Street corners can also be important activity hubs within gang turf areas (Kennedy et al. 1997; Tita et al. 2003) and serve as locations for illicit enterprises such as street-level drug markets (Rengert et al. 2005; Weisburd and Green 1994).

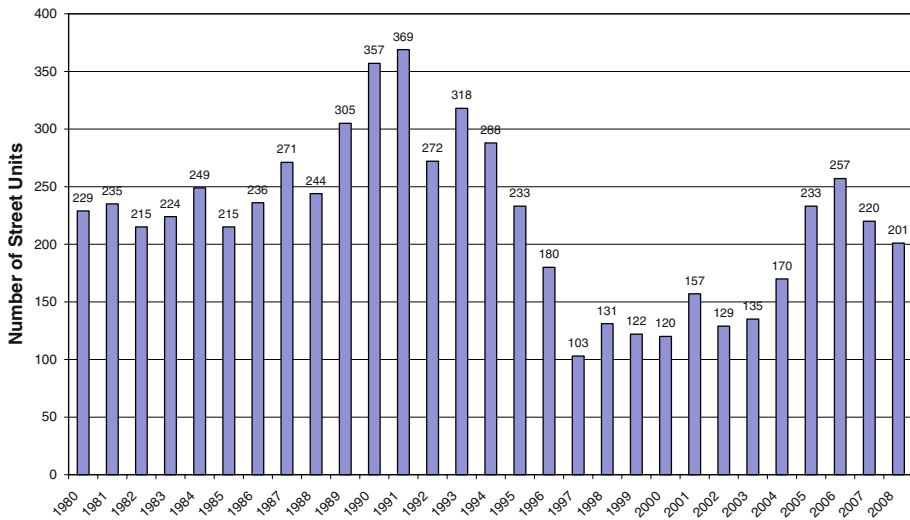
To create a database suitable for executing longitudinal analyses of serious gun violence trends at micro places, we first created a database of records for each street segment and intersection in Boston. We then geocoded all ABDW-Firearm incidents to specific addresses and intersections so yearly counts could be tabulated for each individual street segments and intersections over the study time period. Using ArcGIS 9.3 SP1 and SQL Server 2000 software, we created a database with a record for each of the  $N = 18,155$  street segments and  $N = 10,375$  intersections in Boston. Next, 7,359 ABDW-Firearm incidents were successfully geocoded to a specific street address or intersection (96.8% of 7,602 ABDW-Firearm incidents). Incident reports with a location that could not be geocoded to a specific street segment or intersection (e.g., “Boston Common” or “Franklin Park”) were not included in our analysis. 79.1% of ABDW-Firearm incidents were matched to a specific address on a street segment (5,823 of 7,359) and 21.9% of ABDW-Firearm incidents were matched to a specific intersection (1,536 of 7,359). Geocoded incidents were aggregated to specific street segments and intersections and, for each of these street units, tallied into yearly counts over the 29-year period.

## Analysis

### Distribution of ABDW-Firearm Incidents at Street Segments and Intersections in Boston

For analytic purposes, street segments and intersections were treated as a single unit of analysis called a “street unit” ( $N = 28,530$ ). When aggregated, only 3,294 “street units” experienced at least one ABDW-Firearm incident over the 29-year period (11.5% of 28,530). Put another way, *the vast majority of street segments and intersections in Boston (88.5%) never experienced an ABDW-Firearm incident between 1980 and 2008*. Fig. 2 presents the yearly counts of street units in Boston with at least one ABDW-Firearm incident between 1980 and 2008. The yearly number of street units that experience at least one ABDW-Firearm incident followed the same trajectory as the total yearly counts with 229 street units in 1980 (0.80% of 28,530), a peak of 369 street units in 1990 (1.29% of 28,530), a low of 103 street units in 1997 (0.36% of 28,530), and a second peak of 257 street units in 2006 (0.90% of 28,530). On average, during the study time period, less than 1% of street units (0.78% of 28,530) experienced at least one ABDW-Firearm incident in a given year.

Table 1 presents the distribution of ABDW-Firearm incidents at street units in Boston between 1980 and 2008. While the vast majority of street units in Boston never



**Fig. 2** Combined segments and intersections that had at least one ABDW-firearm incident in Boston, 1980–2008. 3,294 “street units” had at least one ABDW-firearm incident during this time period (11.5% of 28,530)

**Table 1** Distribution of ABDW–firearm incidents at street units in Boston, 1980–2008

<i>N</i> of incidents per street unit	<i>N</i> of street units	% of street units	Cum % street units	Sum of incidents	% of incidents	Cum % incident
10 or more	65	0.23	0.23	1,032	14.02	14.02
5–9	269	0.94	1.17	1,730	23.51	37.53
2–4	1,037	3.63	4.80	2,674	36.34	73.87
1	1,923	6.74	11.54	1,923	26.13	100.0
0	25,246	88.46	100.0	0	0.00	100.0
Total	28,530			7,359		

experienced a single incident, another 6.74% of street units experienced only one ABDW-Firearm incident over the 29-year study period. This table also reveals that particular micro places suffer a vastly disproportionate amount of serious gun violence relative to other micro places in the city; only 65 street units generated 1,032 ABDW-Firearm incidents in Boston between 1980 and 2008. These highly active street units represented only 0.23% of the street segments and intersections in Boston but accounted for 14.02% of ABDW-Firearm incidents between 1980 and 2008. Street units with five or more ABDW-Firearm incidents represented only 1.17% of the street segments and intersections in Boston but accounted for 37.53% of ABDW-Firearm incidents between 1980 and 2008. *Street units with two or more ABDW-Firearm incidents represented only 4.8% of the street segments and intersection in Boston but generated 73.87% of the ABDW-Firearm incidents over the 29-year study time period.*

This striking spatial concentration of gun violence in micro-places faces one important statistical challenge—to some extent, such a concentration may be an artifact of natural clustering of a small number of incidents among a large geographic space. The fact that each year, on average, there are fewer than 254 ABDW-Firearm incidents among nearly 28,530 street units suggests that even a purely random distribution might produce the observed clustering. To address this issue, we constructed a negative binomial distribution of the expected number of street segments that would have between zero and “5 or more” incidents for each 5-year period in the data.<sup>6</sup> Then, we conducted a simple chi-square goodness of fit test to assess the extent to which the observed concentration significantly differs from the randomly generated negative binomial distributions. The results, presented in Table 5 of the Appendix to this paper, clearly demonstrate that in each time period there is significantly more clustering in the observed distribution than in the expected distribution; this is especially true among the “5 or more category.” This finding provides considerable support for the fact that the observed distribution is not merely an artifact of natural clustering.

### Growth Curve Regression Models

As Table 1 suggests, yearly counts of ABDW-Firearm incidents at street segments and intersections in Boston were distributed in the form of rare event counts. There are well-documented problems associated with treating event count variables, which are discrete, as continuous realizations of a normal data generating process (King 1989). As such, methods such as standard mean difference tests and ordinary least squares regression that assume population normality of the dependent variable should not be used to analyze count data (Gardner et al. 1995). Rather, Poisson and negative binomial regression models are generally used to estimate models of the event counts (Long 1997).

In this analysis, we use a variation of a multilevel negative binomial regression model in order to analyze the change in ABDW-Firearm trends at micro places in Boston over the observation period. More specifically, we developed individual growth curve models to estimate street unit changes in ABDW-Firearm incidents over the observation period (Gelman 2005; Singer and Willet 2003). Here we use a longitudinal negative binomial model where we predict within unit variation at level 1 and between unit variation at level 2 using level 1 intercepts and slopes as outcomes. In non-technical terms, we are interested in accurately analyzing the overall serious gun violence trend of *each of the street units* during the observation period. Each street unit is also allowed to have its own slope and intercept in order to model different starting levels of serious gun violence as well as different rates of change.<sup>7</sup> Formally, as shown in Eq. 1, the model is specified as:

$$\Pr(Y_{it} = y_{it} | x_{it} \delta_i) = \frac{\Gamma(\lambda_{it} + y_{it})}{\Gamma(\lambda_{it})\Gamma(y_{it} + 1)} \left( \frac{1}{1 + \delta_i} \right)^{\lambda_{it}} \left( \frac{\delta_i}{1 + \delta_i} \right)^{y_{it}} \quad (1)$$

where  $y_{it}$  is the count for the  $t$ th observation in the  $i$ th group. In the random effects model  $\delta_i$  is allowed to vary randomly across groups; namely, we assume that  $(1/(1 + \delta)) \sim \text{Beta}(r, s)$ . Equation 2 shows the joint probability of the counts for the  $i$ th group is:

<sup>6</sup> Similar results were produced using a Poisson distribution and 3-year intervals.

<sup>7</sup> Fixed-effects negative binomial regression models yield essentially the same results as the findings presented here. The results of the fixed-effects models are available upon request from the authors.

$$\begin{aligned} \Pr(Y_{it} = y_{i1}, \dots, Y_{ini} = y_{ini} | X_i) &= \int_0^\infty \prod_{t=1}^{n_i} \Pr(Y_{it} = y_{it} | x_{it}, \delta_i) (\delta_i) d\delta_i \\ &= \frac{\Gamma(r+s) \Gamma(r + \sum_{t=1}^{n_i} \lambda_{it}) \Gamma(s + \sum_{t=1}^{n_i} y_{it})}{\Gamma(r) \Gamma(s) \Gamma(r+s + \sum_{t=1}^{n_i} \lambda_{it} + \sum_{t=1}^{n_i} y_{it})} \prod_{t=1}^{n_i} \frac{\Gamma(\lambda_{it} + y_{it})}{\Gamma(\lambda_{it}) \Gamma(y_{it} + 1)} \end{aligned} \quad (2)$$

For  $X_i = (x_{i1}, \dots, x_{ini})$  and where  $f$  is the probability density function for  $\delta_i$ . As Eq. 3 shows, the resulting loglikelihood is:

$$\begin{aligned} \ln L &= \sum_{i=1}^n w_i \left[ \ln \Gamma(r+s) + \ln \Gamma\left(r + \sum_{k=1}^{n_i} \lambda_{ik}\right) + \ln \Gamma\left(s + \sum_{k=1}^{n_i} y_{ik}\right) \right. \\ &\quad - \ln \Gamma(r) - \ln \Gamma(s) - \ln \Gamma\left(r+s + \sum_{k=1}^{n_i} \lambda_{ik} + \sum_{k=1}^{n_i} y_{ik}\right) \\ &\quad \left. + \sum_{t=1}^{n_i} \{\ln \Gamma(\lambda_{it} + y_{it}) - \ln \Gamma(\lambda_{it}) - \ln \Gamma(y_{it} + 1)\} \right] \end{aligned} \quad (3)$$

where  $\lambda_{it} = \exp(x_{it}\beta + \text{offset}_{it})$  and  $w_i$  is the weight for the  $i$ th group (Hausman et al. 1984).

Alternatively, previous studies have also employed latent class or semiparametric group based approaches (such as TRAJ models, e.g., Nagin 1999, 2005; Nagin and Land 1993) to predict “groups” of trajectories. These models use an approach similar to factor analysis which reduces large amounts of data into smaller theoretical groups. In so doing, each unit takes the slope (or coefficient) of the entire “grouping.” Although TRAJ models have been used mainly to explain the trajectories of criminal careers, a few studies have applied them to place-based crime data (Griffiths and Chavez 2004; Weisburd et al. 2004). Recently, there has been much debate comparing these group-based approaches and growth curve models such as ones we employ here (e.g., Eggleston et al. 2004; Nagin 2004). While the present study does not wish to directly engage this debate, we wish to recognize this as a viable alternative approach to ours with potentially interesting results.

That said, we employ the longitudinal negative binomial models for two main reasons. First and foremost, our primary research interest is *not* to group street units into specific groups or classes, but rather to assess how the vanguard of ABDW-Firearm trends in Boston are driven by the specific ABDW-Firearm trends of individual geographic units. In other words, growth curve models allow a full characterization of the temporal sequence under consideration for *each* unit over the whole time period (see also Kubrin and Herting 2003). Thus, rather than assign individual street units to groups, we wish to assess individual slopes over the time period. Our analysis finds that once accurate slopes are obtained for each unit, dividing units into quartiles of slopes is an accurate way of portraying data visually and empirically without losing the actual value assigned to individual units.

Our second reason for using these models is an empirical one: there are large numbers of street units that have only one observation point. This suggests that a sizeable portion of all street units have no “trend” per se, but simply experience an isolated event. For this reason, we limited our main analysis to Boston street units with more than one event ( $N = 1,371$ ; see Table 1). It is significant to note, however, that the findings of our models presented below remain robust even when including single-event-only street units.<sup>8</sup>

<sup>8</sup> When the single-event-only street units are included in our growth curve regression models, the results vary only slightly in magnitude. These results are available upon request from the authors.

**Table 2** Summary statistics for key variables in growth curve regression models

Variable	Mean	SD	Range
All street units model, $N = 38,388$			
Number of ABDW-firearm incidents per year	0.136	0.429	0–8
Lagged $N$ of ABDW-firearm incidents per year	0.135	0.425	0–8
Street unit type (0 = intersection, 1 = segment)	0.788	0.408	0–1
Street segments only model, $N = 30,240$			
Length of street segment (Meters)	130.26	85.58	3.33–641.59
Number of ABDW-firearm incidents per year	0.141	0.441	0–8
Lagged $N$ of ABDW-firearm incidents per year	0.139	0.435	0–8
Intersections only model, $N = 8,148$			
Number of ABDW-firearm incidents per year	0.121	0.387	0–6
Lagged $N$ of ABDW-firearm incidents per year	0.122	0.386	0–6

To capture linear and non-linear trends, the final growth curve regression models included Time, Time<sup>2</sup>, and Time<sup>3</sup> as covariates

### Specification of the Growth Curve Regression Models in this Analysis

To ensure that there were no substantive differences in ABDW-Firearm trends at Boston street segments and intersections, we estimated three separate growth curve regression models for intersections only, street segments only, and combined intersections and street segments (i.e., street units described above). For each model, the number of observations was calculated by multiplying the number of street units by the number of years. For instance, in the combined model, there were 38,388 observations derived from 1,371 street units over 28 years.<sup>9</sup>

Table 2 presents the summary statistics for key variables included in our final growth curve regression models. Our dependent variable is the number of ABDW-Firearm incidents reported in each street unit per year. Consistent with prior criminological research which tends to show that past levels of violence are significant predictors of current levels of violence (e.g., Sampson et al. 1997) we included a covariate for the lagged ( $t-1$ ) number of ABDW-Firearm incidents for each street unit. Since longer street segments are at an elevated risk of experiencing an ABDW-Firearm incident, we used ArcGIS 9.3 SP1 spatial analysis tools to calculate the length in meters of each street segment included in the analysis. Since intersections are represented by a point on the map, length could not be calculated for the intersections included in this analysis. However, in our combined model, we included a dichotomous dummy variable indicating whether the street unit was a street segment (1) or an intersection (0). Finally, to account for linear and nonlinear yearly trends in the dependent variable, we included a series of Time, Time<sup>2</sup>, and Time<sup>3</sup> covariates. The base Time variable was measured as the simple linear additive progression for each year over the course of the 29-year observation period.

<sup>9</sup> As discussed below, we lagged the number of ABDW-Firearm incidents for each street unit by 1 year. To calculate this variable, the time series loses the first year of data. Therefore, our final models analyzed 28 years of data rather than 29 years of data.

**Table 3** Results of growth curve regression models

	Street segments only (1)	Intersections only (2)	Combined (3)
Time	−0.0737*** (0.0053)	−0.0839*** (0.011)	−0.0753*** (0.0048)
Time <sup>2</sup>	−0.000819*** (0.00030)	−0.00346*** (0.00065)	−0.00128*** (0.00027)
Time <sup>3</sup>	0.000518*** (0.000042)	0.000657*** (0.000089)	0.000540*** (0.000038)
Length of street segment	0.00136*** (0.00022)		
Lagged <i>N</i> of ABDW—Firearm	0.336*** (0.024)	0.221*** (0.071)	0.332*** (0.023)
Unit type (1 = street segment, 0 = intersection)			0.116*** (0.044)
Constant	146.1*** (10.6)	166.9*** (21.7)	149.6*** (9.51)
BIC	25,162.02	6,204.987	31,367.8
Wald Chi-square	502.16	92.78	540.46
Log likelihood	−12,539.741	−3,070.9744	−15,641.677
Observations (units × years)	30,240	8,148	38,388
Number of “street units”	1,080	291	1,371

Standard errors in parentheses

\*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ 

As Eq. 4 shows, our final full model with all street units takes the following form:

$$Y_{ij} = \alpha_i + B_{1i}(\text{TIME}) + B_{2i}(\text{TIME})^2 + B_{3i}(\text{TIME})^3 + B_{4i}(\text{Lagged ABDW}) + B_{5i}(\text{UnitType}) + \varepsilon_{it} \quad (4)$$

where  $Y_{ij}$  is the annual counts of ABDW-Firearm incidents at each street unit assuming the negative binomial dispersion discussed above.

## Results

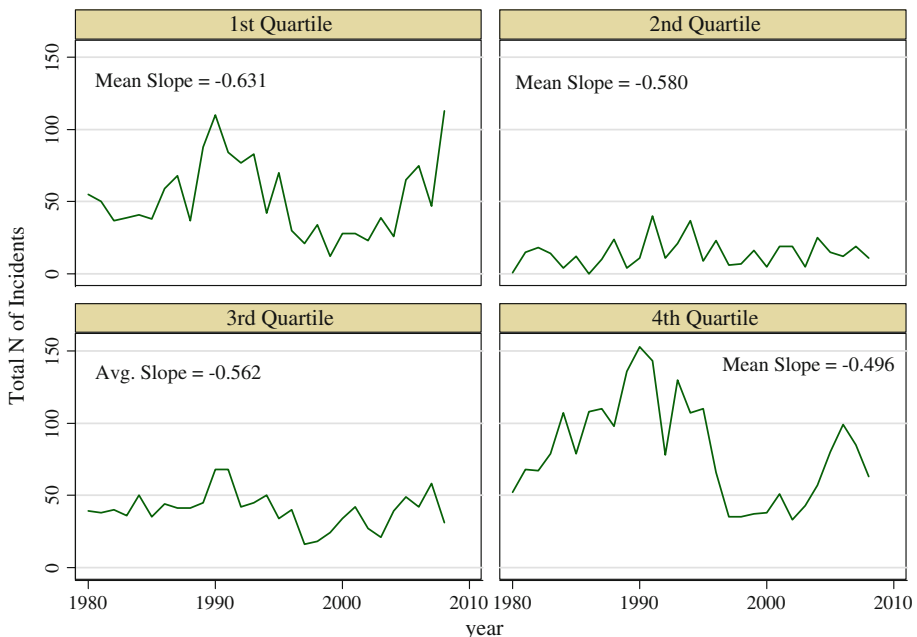
Table 3 presents the results of the three growth curve regression models examining trends in the observed count of incidents per street unit each year. Model (1) presents results of the equation for only the street segments, Model (2) presents the results for only the intersections, and Model (3) presents the results for the combined street units (street segments and intersections). The overall results were consistent across models; this suggests that micro-level serious gun violence trends were similar at street segments and intersections in Boston over the 29-year study time period. In the three models, the negative and statistically significant ( $p < 0.01$ ) coefficients on the Time and Time<sup>3</sup> covariates suggest that ABDW-Firearm incidents as a whole declined among both street segments and intersections in Boston between 1980 and 2008. The positive and statistically significant ( $p < 0.01$ ) coefficient on the Time<sup>2</sup> covariate captures the increases in ABDW-Firearm incidents leading to the peaks in 1990 and 2006.

The positive and statistically significant ( $p < 0.01$ ) coefficient for the lagged number of ABDW-Firearm incidents suggests that street units with higher ABDW-Firearm incidents continue to have higher levels of serious gun violence as time progresses. In Model (1), the

coefficient for the length of street segment is positive and statistically significant ( $p < 0.01$ ). This suggests that longer street segments experience higher numbers of ABDW-Firearm incidents relative to shorter street segments. Model (3) reveals that, when street segments and intersections are combined, street segments tend to experience higher ABDW-Firearm incident numbers as compared to intersections ( $p < 0.01$ ).

Thus far, the growth curve regression analysis simply modeled each street unit's trend over the study time period; post-estimation visual analysis was then used to compare the trends of individual units to the overall citywide trend in serious gun violence. The graphs in Fig. 3 divide Boston street units with more than one ABDW-Firearm incident into quartiles of the predicted linear slope and intercept from the growth curve regression models presented in Table 3. For illustration purposes, we present the mean slope of all Boston street units in that quartile. At face value, there seems to be two basic patterns in these four graphs. Street units in Groups 1 and 4 follow a volatile trend that is very similar to the overall trend in ABDW-Firearm incidents in Boston between 1980 and 2008. While there are some modest peaks and valleys, street units in Groups 2 and 3 are generally stable over the same time period. This suggests that Boston has essentially two types of highly-active street units: those that have volatile gun violence concentrations over time and those that have stable gun violence concentrations over time.

Table 4 presents the distribution of ABDW-Firearm Incidents in Boston between 1980 and 2008 among street units in quartile groups defined by growth curve regression models. Overall, the street units in the four groups accounted for 4.8% of the street units in Boston and 73.9% of the ABDW-Firearm incidents in Boston over the 1980–2008 time period. As the graphs in Fig. 2 suggest, street units in Groups 1 and 4 followed a more volatile trajectory while street units in Groups 2 and 3 exhibited a more stable trajectory. Following these general patterns, these street units were collapsed into two larger groups. Street units



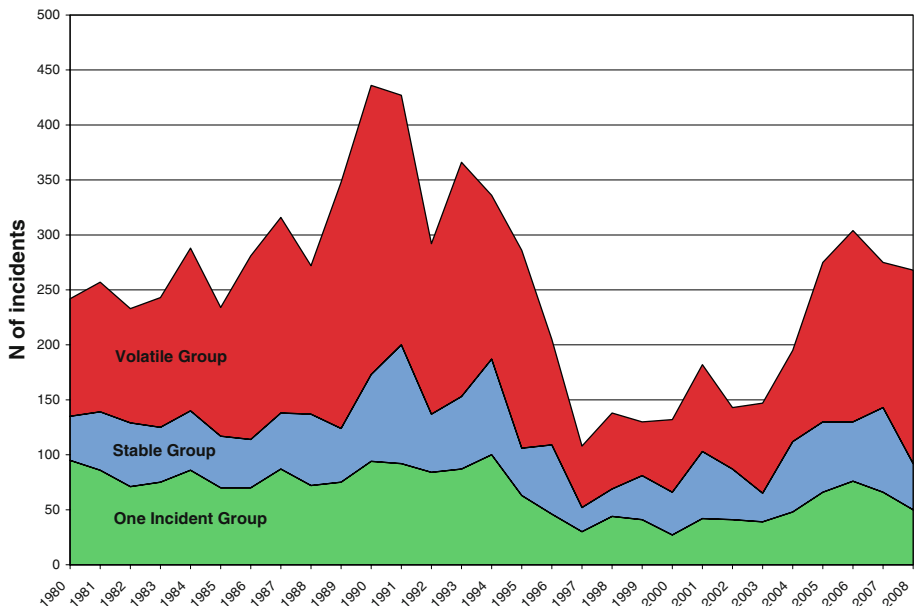
**Fig. 3** Mean slopes of street units in quartiles

**Table 4** Distribution of ABDW-firearm incidents in Boston, 1980–2008, among street units in quartile groups defined by growth curve regression models

Group	N of street units	% of 28,530 street units	Sum of incidents	% of 7,359 incidents
1	571	2.0	1,519	20.6
2	201	0.7	413	5.6
3	332	1.2	1,157	15.7
4	267	0.9	2,347	31.9
Total	1,371	4.8	5,436	73.9
Stable (Groups 2, 3)	533	1.9	1,570	21.3
Volatile (Groups 1, 4)	838	2.9	3,866	52.5
One incident only	1,923	6.7	1,923	26.1

with a “Stable” trajectory accounted for 1.9% of the street units in Boston and 21.3% of the ABDW-Firearm incidents in Boston over the 1980–2008 time period. Street units with a “Volatile” trajectory accounted for 2.9% of the street units in Boston and 52.5% of the ABDW-Firearm incidents in Boston over the 1980–2008 time period. As discussed earlier, street units that experienced only one incident during the entire 1980–2008 time period accounted for 6.7% of the 28,530 street units in Boston and 26.1% of the 7,359 total ABDW-Firearm incidents.

Fig. 4 presents the group yearly counts of ABDW-Firearm incidents in Boston over the study time period. This graph reveals that the street units in the “Volatile” concentration group are responsible for the largest share of the peaks and valleys in gun violence over time in Boston that correspond closely with the gun violence epidemic of the late 1980s and

**Fig. 4** Group yearly counts of ABDW-firearm incidents in Boston, 1980–2008

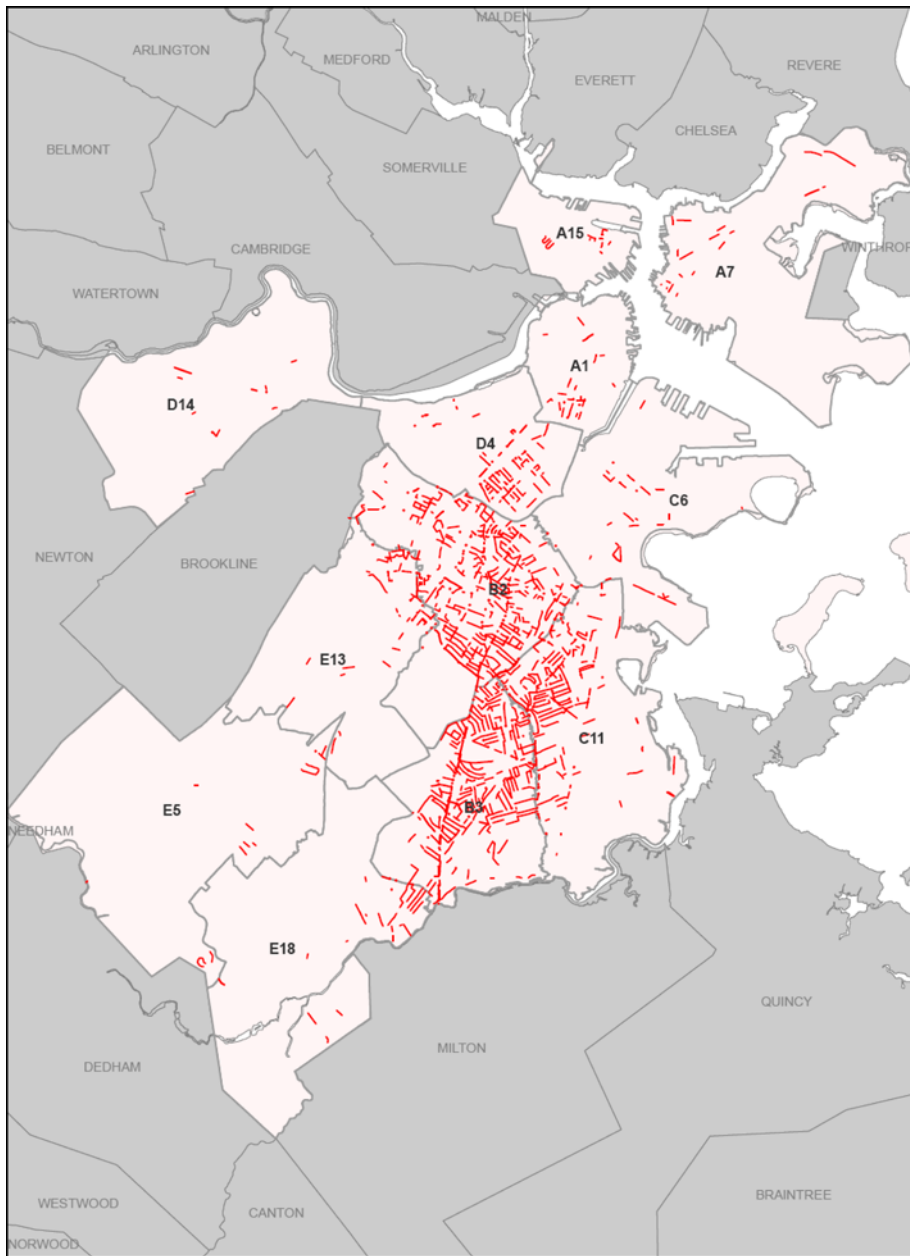
early 1990s, the gun violence drop of the mid to late 1990s, and the post-2004 resurgence in gun violence. The street units in the “Stable” concentration group account for a smaller share of the yearly ABDW-Firearm incidents and exhibit a similar but much more modest trajectory when compared to the “Volatile” group. Street units in the one incident only group follow a generally stable trajectory that is congruent with overall citywide trends in gun violence but without the steep upturns and downturns.

Fig. 5 presents a Boston map that reveals the geography of the street segments and intersections in the “Volatile” and “Stable” trajectory groups. These high-gun violence activity street units tend to cluster along major thoroughfares, like Blue Hill Avenue and Washington Street, that run through Roxbury, Dorchester, and Mattapan. Groups of these high-gun violence activity street units cluster in well-known gun violence hot spot areas such as the Lenox Street/Lower Roxbury area, Heath and Academy housing projects, Egleston Square, Dudley Square, Orchard Park housing project, Grove Hall, Franklin Hill housing project, Franklin Field housing projects, and Morton and Norfolk Streets neighborhood (see Braga et al. 2008).

## Conclusion

Our analyses suggest that city-level gun violence trends may best be understood by the analyses of trends at a very small number of micro places, such as street segments and intersections, rather than analyses of trends at larger areal units such as neighborhoods, arbitrarily-defined policing districts, or Census tracts. These levels of aggregation may obscure important place-based dynamics that vary within larger geographic boundaries. As Fig. 5 suggests, a longitudinal spatial analysis of gun violence trends at larger spatial units in Boston Police Department’s District D-4, covering the Back Bay, Fenway, South End, and Lower Roxbury neighborhoods, would miss important micro-level variations associated with particular street segments and intersections that surround and include historical gang turfs and rivalries in the Lenox Street, Villa Victoria, and Castle Square housing projects (located in Fig. 5 in the D-4 areas with the dense concentrations of high-activity gun violence street units).

Our analyses also suggest that the “flood in a canyon” characterization of the gun violence epidemic of the late 1980s and early 1990s may actually be an understatement. Defining the at-risk population as including young, minority males living in disadvantaged neighborhoods is not refined enough to capture the extreme concentration of gun violence in urban environments. Urban gun violence trends may be best understood as generated by a very small number of high-risk individuals who participate in high-risk social networks and perpetrate their shootings at a very small number of high-risk micro places. In 2006, about 1% of Boston’s youth ages 15–24 participated in gangs and these gangs accounted for 50% of total homicides, 77% of youth homicides, and 70% of fatal and non-fatal shootings in Boston (Braga et al. 2008). These findings are consistent with previous research on the high concentration of gun violence among a small number of gang-involved individuals during the early to mid-1990s (Kennedy et al. 1997). In this analysis, almost 89% of Boston street segments and intersections never experienced a single ABDW-firearm incident between 1980 and 2008. Some 6% of street segments and intersections experienced a single ABDW-firearm incident during this same time period. Boston gun violence trends were largely generated by repeated incidents at less than 5% of its street segments and intersections; the gun violence epidemic and sudden downturn was



**Fig. 5** The spatial distribution of micro places with stable and volatile concentrations of serious gun violence in Boston

almost completely driven by trends at about 3% of the city's micro places that exhibited volatile concentrations of serious gun violence over time.

Many analyses of the spread of lethal gun violence during the epidemic of the late 1980s and early 1990s sought to determine whether homicide spatially diffused across

communities and, if it did, to articulate the mechanism(s) associated with the spread over time. As Blumstein and Cohen (2002, p. 8) suggest,

It was hypothesized that, similar to the role of a mosquito in transmitting malaria, guns serve as a vector of the homicide epidemic. Presumably the presence of guns is transmitted from individuals directly involved in crack markets or youth gangs, and the neighborhoods in which these enterprises are located, to other non-participating youths. Those others would likely be peers from the same neighborhood or adjoining neighborhoods, but could also be physically more remote because social networks are not necessarily confined geographically.

To the extent that gun violence does diffuse across urban landscapes, our analyses suggest that spatial diffusion would be limited to very few locations within so-called violent neighborhoods. Our analyses suggest that gun violence upswings and downturns are largely concentrated at a small number of gun violence hot spots that intensify and diminish over time. It is possible that gun violence trends at these places follow trajectories that are consistent with a spatial diffusion process (e.g., a suddenly “hot” street corner that drives up gun violence levels on surrounding street corners over the course of several months). In future analyses, we will examine spatial and temporal diffusion of assaultive gun violence across street segments and intersections in Boston. In particular, we will search for evidence of contagion of gun violence among adjacent street segments and intersections.

Finally, these findings strongly support the perspective that a city’s portfolio of gun violence prevention programs should include interventions that are explicitly place-based; that is, certain prevention efforts should be focused in very specific locations rather than diffused across larger neighborhoods. For instance, there is a growing body of research that suggests hot spots policing is effective in preventing crime (Braga 2001; Skogan and Frydl 2004; Weisburd and Eck 2004). Hot spots policing programs have also been shown to produce crime prevention benefits when focused on places with high level of violent gun crimes (Cohen and Ludwig 2003; McGarrell et al. 2001; Sherman and Rogan 1995). Police executives should explicitly deploy officers to these locations with the charge of enhancing their visibility, increasing contacts with potential offenders, and engaging community problem solving techniques to understand the underlying conditions that give rise to these violent places.

Social service and opportunity provision programs should also be oriented towards particular street corners and blocks that generate high levels of gun violence. For instance, street outreach workers can be deployed in these areas to work with gang-involved and criminally-active youth who are at an elevated risk of shooting someone or being shot themselves (Kennedy et al. 1996; Skogan et al. 2008). It is obviously important to consider addressing the social networks and relations among groups that drive violent behavior that is manifested in repeated gun assaults at particular places. If gun violence can be reduced at a small number of micro places in the city, citywide gun violence rates will be positively impacted.

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## Appendix

See Table 5.

**Table 5** Distribution of ABDW-firearm incidents in Boston by observed and expected number of street units each year, (a) 1980–1984, (b) 1985–1989, (c) 1990–1994, (d) 1995–1999, (e) 2000–2004, and (f) 2005–2008

	1980–1984		1985–1989		1990–1994	
	Observed	Expected	Observed	Expected	Observed	Expected
0	27,565	28,227	27,529	28,242	27,309	28,141
1	791	210	776	200	883	239
2	112	70	129	55	201	104
3	35	14	56	21	76	25
4	9	9	17	6	27	13
5+	18	0	23	6	34	8
Chi-square	1.18e + 0.04, $p = 0.000$		6.5e + 04, $p = 0.000$		3.8e + 04, $p = 0.000$	

	1995–1999		2000–2004		2005–2008		Total	
	Observed	Expected	Observed	Expected	Observed	Expected	Observed	Expected
0	27,872	28,339	27,904	28,341	27,753	28,287	5,236	27,250
1	528	132	506	120	572	164	1,923	717
2	86	47	87	46	129	53	598	291
3	23	7	23	16	45	19	278	143
4	16	5	5	4	16	5	161	63
5+	5	0	5	3	15	2	334	66
Chi-square	1.8e + 04, $p = 000$		1.2e + 04, $p = 0.000$		1.9e + 04, $p = 0.000$		2.1e + 05, $p = 0.000$	

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